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Abstract

Why do Scandinavian countries perform better in terms of environmental protection than other European Union countries? In this paper, we explore the hypothesis that societies characterised by low income inequality (such as the Nordic European countries) generate political-economic equilibria where environmental policy is more stringent.

We model an overlapping-generations economy in which individuals differ in skills to address the question to what extent in modern democracies, income distribution influences the stringency of environmental policy and consequently the growth of a country. Individuals work when they are young and own capital when they are old. Pollution externalities are present due to the use of a polluting factor. The government uses the revenue from a capital-income tax and a pollution tax for a lump-sum transfer to the old generation. The fiscal decision at each point in time is taken by a majority elected representative. In politico-economic equilibrium, the lower the skill of the median individual is relative to the average, the smaller the pollution tax and the capital stock are, and the greater the capital income-tax and the relative use of the polluting factor. We perform both steady-state analysis and examine the transition path. Subsequently, we present an empirical analysis for two panels of seven and ten industrialised countries from the late seventies to late nineties. Our framework is able to explain the stylised facts regarding inequality, environmental protection, and growth.

Keywords: Environmental policy, majority voting, endogenous fiscal structure, income distribution, overlapping generations, growth.

JEL classification: D62, D72, E62, H20.

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1. INTRODUCTION

The protection of the environment is on the agenda of the governments of most modern democracies; nevertheless, we observe that developed countries show different levels of environmental protection, even if their macroeconomic performance is similar. For example, a new index of environmental sustainability, developed by the Yale Centre for Environmental Law and Policy, which ranks countries according to the effectiveness of environmental policies,[1] shows how different the performances among European countries are. Scandinavian countries appear to be the most environmentally friendly, while Belgium, Italy, and Spain are among the least so. France, the Netherlands, Germany and the UK perform in between.

There may be individual-specific factors at work when it comes to decisions about environmental policy. In the social science literature, there has been a recent interest in what influences public support for environmental projects. That literature claims that there is an array of individual socio-demographic characteristics, such as age, education, gender, race, ideology, party affiliation, and urbanization, together with economic variables, including work status and individual's income, which are relevant for public opinion formation.[2] If, in particular, it is believed that individual's income is influential, one may expect that income distribution within a country is a factor in shaping that country's environmental policy. Consequently, from casual observations, we may speculate that societies in which income is distributed more equally, such as the Scandinavian countries, are typically characterised by

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1 See *The Economist*, January 29th 2000 issue, p.138.

2 Most of the existing studies in social sciences have empirically investigated the significance of these factors in explaining public support for environmental protection. For example, Elliot et al. (1997) find that both socio-demographic and economic factors are influential in the US, while in Blake et al. (1997), income- and education levels are not significant in explaining environmental concern among Canadian households. Newell and Green (1997), on the other hand, find that consumers' environmental concern is not different between white and black people at high levels of income and education (i.e., only individual income and education matter for public opinion towards the environment). Kahn and Matsusaka (1997) finds that individual income and the price of the environmental good can explain most of the variation in voting.

a stricter environmental policy than notoriously "unequal" societies, such as Italy, Spain, the UK. However, little attention has been devoted to the analysis of how income inequality influences political decisions about the protection of the environment.[3]

On the contrary, an extensive literature already exists on the links from income distribution to economic growth, through the political-economy channel. The main idea is that more unequal societies, in terms of skewness of the distribution, prefer more on redistribution, which in turn discourages investment and growth (see Persson and Tabellini, 1994, and Benabou, 1996). Furthermore, there is empirical evidence of a negative correlation between inequality and growth in developed countries (see the survey by Benabou, 1996).

The relationship between environmental policy and growth has also been explored, although not in an endogenous policy framework. The common view among policy makers and industrialists is that environmental policy hampers growth, see e.g. van der Ploeg and Withagen (1991), and Ligthart and van der Ploeg (1994). However, there are recent papers which show that, under certain conditions, environmental policy can boost economic growth (see, for example, Bovenberg and de Mooij, 1997; Bovenberg and Smulders, 1995 and 1996; Gradus and Smulders, 1993 and 1996; Nielsen, Pedersen and Sorensen, 1995; Xepapadeas, 1994). Other studies focus on the relationship between growth, environmental policy, and redistribution across generations (John and Pecchenino, 1994; Fisher and van Marrewijk, 1998). Those papers analyse policy-reform experiments, and not endogenously determined policy.

Another body of literature focuses on the influence of lobby groups on political-economic equilibrium environmental policy (see, among others, Fredriksson, 1997 and Aidt, 1998). In

[3] Oates and Schwab (1988) develop a static endogenous policy model in which individuals are distinguished as wage and non-wage earners and the median voter takes decisions over a capital tax and a standard for local environmental quality, to focus on the issue of tax competition across jurisdictions.

the current paper we do not model special-interest group politics in order to focus more clearly on the role of income inequality.

The purpose of our paper is twofold: first to analyse how, in democracies, individual income distribution influences political decisions about environmental protection, and, second, to determine how environmental protection and economic growth are interrelated in political-economic equilibrium. The main hypothesis of this paper is that if we observe a negative correlation between inequality and growth and between inequality and environmental protection, we can explain a positive correlation between environmental protection and growth.[4]

In our paper, the level of environmental protection is determined endogenously, by a majority elected representative. Therefore our paper distinguishes itself from most of the related literature on growth and the environment that it focuses on endogenous taxation rather than on environmental tax reforms. In order to address the growth issue, we need a dynamic framework. It is very difficult to solve political-economic equilibria in dynastic models because individuals voting today would have to predict all future political-economic equilibria, which will be a function of how individuals vote today. Such a model can only be solved if one resorts to computation. We therefore choose an overlapping-generations economy, where individuals (because of two-period lives) do not have to know all future political-economic equilibria. We can then solve a sequence of political equilibria and still allow for dynamics of the underlying economy. The model we present may be given different interpretations, though we wish to stress the overlapping-generations interpretation (see section 2).

One version of the overlapping-generations model has already been used in the analysis

[4] Our paper, although related, does not focus on the environmental Kuznets-curve analysis, where one is interested in the development of environmental protection as a function of national income over time. The Kuznets-curve analysis ignores distributional issues.

of inequality and growth by Persson and Tabellini (1994) and Benabou (1996), among others. We augment this framework by including a pollution factor of production, the use of which is taxed by the government. In our model, the young generation work and the old generation own the capital. Individuals in the young generation differ in ability to earn labour income. We will focus on one type of benefit: lump-sum transfer to the old, which can be thought of as social security. Furthermore, we will explicitly model environmental policy which consists of taxation of a polluting factor (for example, energy). The fiscal decision is taken by a majority-elected representative, a period in advance, and is thus endogenised.

This framework permits us to answer a number of questions: How do individuals' characteristics such as ability and, consequently, income inequality influence the decisions regarding pollution taxes? What is the role of income inequality in explaining different patterns of environmental protection? And how does the preferred environmental policy affect the economic growth of a country?

We first conduct an analysis of individuals' preferences over the pollution tax, for general preferences and (constant returns to scale) production technologies, in a neighbourhood of no inequality. There are two driving forces. First, environmental policy results in loss of production possibilities. Different individuals evaluate the production loss differently. Individuals with a higher marginal utility of consumption (the poorer ones) have a lower marginal rate of substitution between environment and private consumption if environment is a non-inferior good. Second, a poorer individual typically wishes to redistribute (using tax instruments on income) from richer individuals. The redistribution causes the consumption-possibilities frontier to move inwards (due to efficiency losses). In such an equilibrium, if the environment is a normal good, the marginal rate of substitution between environment and private consumption decreases (for all individuals).

In the next step of the analysis, we use a specific utility function over private consumption and a specific production function. We find that if inequality is high and the median voter is a low-skilled (poor) individual, in politico-economic equilibrium, redistribution is higher, environmental policy laxer and growth is lower.

The final part of the paper is devoted to checking whether our theory is supported by empirical evidence. We use two panels of seven and ten industrialised countries from the late seventies to the late nineties and perform regression analysis for polluting air emissions per GDP level (a proxy for stringency of environmental protection) and for growth. The predicted relationships between inequality, environmental protection, and growth are found.

The paper is organised as follows. The general model is introduced in section 2. In section 3 the economic equilibrium is solved for. In section 4 individuals' preferences over taxation are characterised for the general case, in a neighbourhood of no inequality. Section 5 characterises preferences over policy, for specific functions, but with global results. Section 6 solves for the politico-economic equilibrium as a function of individual's abilities. Section 7 presents the empirical evidence and section 8 summarises and interprets the results.

2. THE ECONOMY

We will specify a general model that contains three different cases. The first case (case I) is a static economy in which output is produced by labour and pollution. Labour and pollution are taxed at possibly different rates, and the tax receipts are redistributed lump-sum to the individuals. Individuals differ in time endowments. This implies that individuals with less productive time will supply less labour (than those with more productive time) if consumption is a normal good. There will then be a redistributive conflict, since the less endowed individuals gain from taxation of labour. This is similar to the Meltzer-Richard (1981) model, but augmented for pollution.

The second case (case II) is a sequence of two-period economies. Individuals live for two periods, consuming in both periods, but only working when they are young. Generations of different ages never co-exist. This is the same set-up used by Persson and Tabellini (1994), but augmented to allow for pollution. The period-one good is produced by labour (exogenous in supply), and the period-two good by capital (saved from the previous period) and pollution. Taxes are levied on capital income and on pollution, and a lump-sum transfer is given when the individuals are old. We allow for either no growth (period 1 wage fixed) or endogenous growth (period 1 wage a function of last generation's capital accumulation).

The third case (case III) is an overlapping-generations economy (similar to Renström, 1996, but augmented for pollution). Output in each period is produced by labour (inelastically supplied by the young), capital (supplied by the old), and pollution. The decision about taxes is taken one period in advance (the young decide on taxes to be implemented when they are old). Taxes are levied on capital income and on pollution, and the transfer is given to the old generation.

In order to understand how inequality may affect the pollution tax, we begin with a general utility specification and a general (constant returns-to-scale) production technology. We may then see to what extent various specific assumptions affect the results. For the general case, we will only look at one situation. This is when inequality is marginally increased from a situation with full equality.[5] In the next section, we will look at global results, but then for specific functional forms.

Denote the two consumption goods (consumed by individual *i*) as c_1^i and c_2^i, respectively. The individual may transfer some of commodity 1 (k_1^i) into commodity 2 at the after-tax rate *p*. The individual has an endowment of commodity 1, w_0^i, and receives a transfer of commodity 2, *S*. In case (I) (the static model), c_1^i is leisure, c_2^i is consumption, k_1^i is labour supply, *p* is the after-tax wage, and w^i is the individual's time endowment. In cases (II) and (III) (the dynamic economy with and without separation across generations), c_1^i and c_2^i are period 1 and 2 consumption respectively, k_1^i is savings, *P* is the after-tax return on savings, and w^i is period-1 labour income. We assume that $w_0^i=\gamma^i w_0$, and that the distribution of γ^i (denoted $\Gamma(\gamma^i)$) is continuous and, for cases (II) and (III), stationary over time. $\Gamma(\gamma^i)$ is also normalised so that the average γ^i equals unity, and so that averages equals aggregates. We will denote averages/aggregates by omitting superscript *i*.

Throughout we will make one separability assumption: the pollution externality enters the individuals' utility functions in a weakly separable way. This will make the individuals' marginal rates of substitutions between private consumption units independent of the pollution externality. This will make the private consumption decisions independent of pollution; without such a separation, the problem becomes intractable and one would have to resort to computation. The weak separability will *not*, however, make the individuals' evaluation of the

5 This is analogous to the optimal tax literature. A situation in which one solves for an optimal tax system, and evaluates it at zero tax rates, is a situation in which one marginally introduces the second best from a first-best situation (no taxes).

environment independent of their private consumption, and, consequently, we may explore this interaction in the analysis. We next state the assumptions made.

2.1 Assumptions

A1 Individuals' preferences

We assume weak separability between private consumption and pollution

$$V^i = V\left(u(c_1^i, c_2^i), x\right) \tag{1}$$

where V and u are strictly concave, and $V_1>0$, $V_2<0$, $u_1>0$, $u_2>0$.

A2 Individuals' constraints

The individuals' budget constraints are

$$c_1^i + k^i = w\gamma^i \quad (2) \qquad\qquad c_2^i = pk^i + S, \quad p \equiv (1-\tau^k)r \quad (3)$$

A3 Production

A large number of firms are operating under identical *constant-returns-to-scale* technologies. Therefore aggregate production, y_t, can be calculated as if there was a representative firm employing the aggregate quantity of the factors supplied by the individuals, ($k \equiv \int k^i d\Gamma(\gamma^i)$ and, in case (III) ($l \equiv \int \gamma^i \, l d\Gamma(\gamma^i)$), and the polluting factor.[6] For case (I) and (II)

$F(k, x)$ (4*a*), and for case (III) $F(k, x, l)$. (4*b*)

Firms take the factor prices of labour (w), capital (R), and the pollution tax τ^x, as given.[7]

6 The polluting factor is provided at no cost. Thus, in absence of a government taxing or regulating it, this factor would be used up until the satiation point.

7 Note that w_0 is labour income in the previous period, and w is labour income earned by the next generation to come.

A5 Government's constraint

The tax receipts are fully used for the lump-sum transfer

$$S = \tau^k R k + \tau^x x \tag{5}$$

A6 Representative democracy

The tax rates, τ^k and τ^x, are determined by a majority-elected representative one period in advance. We assume that one candidate of each type runs for office, and that candidacy is costless.

3 ECONOMIC EQUILIBRIUM

In this section, the individual and aggregate economic behaviour are solved for any given arbitrary sequences of tax rates.

3.1 Individual economic behaviour

Maximisation of (1) subject to (2)-(3) gives the individuals' optimal decision over *k*. The first-order condition forms an implicit function

$$\phi = -u_1\left(w_0^i - k^i, pk^i + S\right) + pu_2\left(w_0^i - k^i, pk^i + S\right) = 0 \tag{6}$$

which differentiated gives the following partial derivatives

$$\frac{\partial k^i}{\partial w^i} = N_2^i \quad (7) \qquad \frac{\partial k^i}{\partial p} = \frac{u_2^i}{D^i} - \frac{k^i}{p} N_1^i \quad (8) \qquad \frac{\partial k^i}{\partial S} = -\frac{N_1^i}{p} \quad (9)$$

where

$$N_1^i \equiv \frac{pu_{12}^i - p^2 u_{22}^i}{D^i} \quad (10) \qquad N_2^i \equiv \frac{-u_{11}^i + pu_{21}^i}{D^i} \quad (11) \qquad D^i \equiv -u_{11}^i + 2pu_{12}^i - p^2 u_{22}^i > 0 \quad (12)$$

Equation (12) is the negative of a quadratic form in the Hessian of *u*. Since *u* is strictly concave, any quadratic form is negative, implying *D*>0 (this is the second-order condition, equation (6) would not characterise a maximum if u was not concave). N_1 and N_2 are ratios of second derivatives of u, and their signs are a property of the utility function. N_1 is positive (negative) if c_1 is a *normal* (*inferior*) consumption good, and N_2 is positive (negative) if c_2 is a *normal* (*inferior*) consumption good. Furthermore, $N_1 + N_2 = 1$, implying that, at most, one of the goods can be inferior. We will see later what role the normality of the private consumption goods plays in the analysis.

As follows from (7), a richer individual will supply more of factor k if c_2 is normal. Any increase in commodity-1 endowment will cause the individual to transfer a part into commodity 2. In a static economy, a more time-endowed individual will work more; in a dynamic economy, an individual with more labour income will save more. If the price of k increases (equation (8)), and commodity 1 is normal, the effect on the supply of k is ambiguous. The reason is that the substitution effect tends to increase k (commodity 2 becomes relatively cheaper), and the income effect tends to decrease k (the individual wishes to consume more of commodity 1 as well). Finally, an increase in the (commodity-2) transfer decreases the supply of k if commodity 1 is normal (the individual wishes to transfer from commodity 2 to commodity 1). Note that normality implies that the more endowed individuals will, in equilibrium, supply more of the taxable k. Taxes can then be used to transfer income from rich to poor.

3.2 Aggregate economic behaviour

Aggregate economic behaviour is obtained by integrating (7)-(9) over the population. We will denote those functions without individual superscripts.

3.3 Firms' behaviour

Firms take prices as given. Profit maximisation implies that the before-tax prices are given by $r=F_k$ (in cases (I), (II), and (III)), and $w=F_l$ (in case (III)). Notice that in case (III), w is the wage received by the next generation (the present generation receives w_0, which is labour's marginal product in the previous period). The first-order condition for the use of factor x, $F_x(k,x,l)=\tau^x$, gives (aggregate/average) x as a function of (aggregate/average) k and τ^x (and of l which, however, is fixed), with the following property

$$dx = d\tau^x/F_{xx} - (F_{xk}/F_{xx})dk \tag{13}$$

3.4 Government's budget

The budget may alternatively be written as

$$S = F - F_l l - pk \tag{14}$$

From (14) and the above equilibrium conditions, we see that a pollution tax and an emissions standard are *equivalent instruments*. We will define environmental strictness as the level of τ^x, which implies that if the government operates an emissions standard, the strictness measure is the (equilibrium) marginal product of pollution, F_x.

4. PREFERENCES OVER POLICY (GENERAL CASE)

An elected individual will choose policy so as to maximise her own utility. This policy is then a function of the type of individual, say γ^*. Substituting this policy into any other individual's utility function one obtains an indirect utility function of γ^* only. It is clear, since individuals differ only in one dimension, our political equilibrium will be of the median voter type. This is a political equilibrium if individuals' indirect utilities over γ^* are single peaked (see further section 6). This will typically be the case if policy is monotone in the candidate γ^*. The first step in solving for the equilibrium is to characterise the decision of an arbitrary candidate. We will first do so for the case in which a candidate is "close" to the average. We analyse a situation where we move from the first best (all individuals the same) to the second best. The aim is to understand the driving forces behind inequality and environmental policy.

We also wish to understand to what extent access to redistributive instruments (other than a pollution tax) affects the results. If the decisive individual does not have access to τ^k, the marginal return to individuals on factor k equals the producer price, so that F_k-P=0 becomes an extra constraint. Denote the multiplier associated with this constraint as μ. We can then capture both situations, depending on whether μ equals 0 or not. The problem of the decision maker i is to

$$\max_{p,s,x} \; V\left((w^i - k^i, pk^i + S), x\right) + \lambda\left[F(k,x,l) - pk - F_l l - S\right] + \mu\left[F_k(k,x,l) - p\right] \tag{15}$$

The problem is written as if the individual was to choose x directly (for example, imposing an emissions standard); however, it is just an equivalent representation of the situation where the pollution tax is chosen. This reflects the equivalence between emissions standards and pollution taxation. This holds because firms all have the same production technology, and therefore no extra informational requirements are needed. The first-order conditions are

$$V_1 u_2 k^i + \lambda\left[(F_k - F_{lk} l - p)\frac{\partial k}{\partial p} - k\right] + \mu\left[F_{kk}\frac{\partial k}{\partial p} - 1\right] = 0 \tag{16}$$

$$V_1 u_2 + \lambda\left[(F_k - F_{lk} l - p)\frac{\partial k}{\partial S} - 1\right] + \mu\left[F_{kk}\frac{\partial k}{\partial S}\right] = 0 \tag{17}$$

$$V_2 + \lambda\left[F_x - F_{lx} l\right] + \mu F_{kx} = 0 \tag{18}$$

We may observe the following. Since the pollution tax is pollution's marginal product, (18) may be written as $\tau^x = F_{ll} + (-V_2)/\lambda - \mu F_k/\lambda$. Everything being equal, an increase in λ (the decisive individual's marginal utility of lump-sum income at the optimum) reduces the pollution tax. Environmental policy comes at the expense of production possibilities. This tends to make poorer individuals (with lower marginal rate of substitution between environment and private consumption) wanting a lower pollution tax. Furthermore, λ is also evaluated at equilibrium production. If the individual is relatively poor and uses redistributive tax instruments, this tends to increase λ further, because of the loss of efficiency. If the decision maker has no access to taxation of *k*, but would have used such a tax, then μ is less than 0. Consequently, a higher λ tends to reduce the pollution tax through the last term if $F_k>0$. The reason is that the pollution tax acts as an implicit tax on *k* by reducing its marginal product (if $F_k>0$). There are two opposing effects. If the tax system is less complete, the link between the decisive individual being poorer and the wish to tax pollution less may be weaker. However, using the pollution tax for redistribution is a less efficient instrument and λ is then higher when no tax on *k* is available. In the end, the effect of less complete tax instruments is ambiguous.

The argument put forth above is just to illustrate what we believe are the driving forces. We need to prove that λ is larger for a poorer individual if she was to choose policy than it would be for a richer individual if the latter were to choose policy. We also need to take into account how individuals evaluate the environment. If *V* is not additively separable, then V_2 depends on the private consumption of the decisive individual (at the optimum) as well. For example, it could be the case that a poorer individual values the environment more (for example, $-V_2$ could be larger for poorer individuals). Furthermore, there is also an effect (in case (III)) regarding the return to labour of the young generation, which the present decisive individual does not care about, but would rather use the tax system so as to reduce the next generation's labour income. In order to formally prove the link between the income of the decisive individual and environmental protection, we need to take into account the whole system (16)-(18). We will do so by performing comparative statics, by changing γ^i of the decision maker, and evaluating the consequences on τ^x in a situation with no inequality. We can then see the consequences of making the decision maker (marginally) poorer or richer than average.

We will conduct the analysis for the situation with a complete tax system (μ=0).

Setting μ=0 and combining (16) and (17) gives

$$k - k^i = \left(F_k - F_{lk} l - p\right)\left(\partial k/\partial p - k^i \partial k/\partial S\right) \tag{19}$$

First, in case (I) and (II), F_{lk} is zero (production technology (4*a*)). Then the capital tax is positive (zero/negative) if the decisive individual supplies less (equal/more) of *k* than the average.[8] In case (II), the future generation will earn wage income, and by choosing a larger capital tax, labour income is reduced (if $F_{lk}>0$) and an implicit transfer from the future young is accomplished. Thus, here, even if the decisive individual owns capital exactly equal to the average (e.g., if full equality), capital would be taxed. Equation (19) forms an implicit function in γ^i, *p*, *k*, and *x* (the latter two being functions of policy). Differentiating and evaluating at $k^i=k$ (full equality) gives

$$-\frac{\partial k^i}{\partial w} dw_0^i = \left[\left(F_{kk} - F_{lkl} l\right) dk + \left(F_{kx} - F_{lkx} l\right) dx - dp\right]\left(\frac{\partial k}{\partial p} - k^i \frac{\partial k}{\partial S}\right) \tag{20}$$

Using (8)-(9) to substitute for the expression in parenthesis, and using (13) to substitute for *dx* yields

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8 If Engel curves are linear, this is the case if the individual has γ smaller (equal/greater) than unity (i.e., average).

$$u_1^{-1} N_2 \boldsymbol{D} d w_0^i = \sigma \, dk + \eta \, d\tau^x + dp \tag{21}$$

where

$$\sigma \equiv -\left(F_{kk} - F_{lkl} l - \left(F_{kx} - F_{lkx} l\right) F_{xk} / F_{xx}\right) \quad (22) \qquad\qquad \eta \equiv -(F_{kx} - F_{lxk} l)/F_{xx} \quad (23)$$

Equation (21) gives the after-tax return p as a function of the decisive individual's endowment w_0^i, of the pollution tax τ^x, and of the level of k (in turn a function of p and τ^x). If we consider cases (I) and (II), (production technology (4*a*)), σ=0. Then for each level of τ^x, the after tax return p is increasing in w_0^i if commodity 2 is a normal good. If factor k's marginal product increases with pollution (F_k>0) η>0, then an increase in τ^x (everything else equal) reduces p. The reason is that an increase in τ^x reduces x and thereby reduces F_k, and it is not optimal to reduce the tax on k so as to leave $p=(1-\tau^k)F_k$ unaffected.

Next, we combine (17) and (18) to obtain the optimality condition for τ^x.

$$\frac{V_1 u_2}{-V_2} = \frac{1 - \left(F_k - F_{lk} l - p\right) \dfrac{\partial k}{\partial S}}{\tau^x - F_{lx} l} \tag{24}$$

We need to know how the marginal rate of substitution between private consumption and the environment changes with the underlying variables. Let V_j denote the derivative of V with respect to argument j={1,2}, we then have

$$dV_j = V_{j1}\left[u_1 dw_0^i + u_2\left(k^i dp + dS\right)\right] + V_{j2} dx \tag{25}$$

differentiating (14) gives

$$dS = \left(F_k - p - F_{lk} l\right) dk + \left(F_x - F_{lx} l\right) dx - k dp \tag{26}$$

using (19) and evaluating at $k^i = k$ gives

$$kdp + dS = (F_x - F_{lx} l)dx = -V_2/(V_1 u_2)dx \tag{27}$$

where the last inequality follows from (18), evaluated at no inequality (i.e. $\lambda = V_1 u_2$). Substituting the last equality of (27) into (25) gives

$$dV_j = V_{j1}\left[u_1 dw_0^i - (V_2/V_1)dx\right] + V_{j2}dx \tag{28}$$

or after rearrangement

$$\frac{dV_1}{V_1} - \frac{dV_2}{V_2} = \left(\frac{V_{11}}{V_1} - \frac{V_{21}}{V_2}\right)u_1 dw_0^i - \frac{V_2}{V_1}Qdx \tag{29}$$

where

$$Q = \frac{V_{11}}{V_1} - 2\frac{V_{12}}{V_2} + \frac{V_1}{V_2}\frac{V_{22}}{V_2} < 0 \tag{30}$$

Equation (30) is a quadratic form in the Hessian of V and is negative since V is strictly concave. Equation (29) gives the change in the individual's marginal rate of substitution between the private consumption index, u, and the environment. If the environment is a normal consumption good, the first term on the right-hand side is negative, implying, at the optimum, that a richer individual has a lower marginal rate of substitution and thus prefers to substitute less from the environment to private consumption. This effect makes a poorer individual wish to protect the environment less. The second term on the right-hand side is negative, implying that the marginal rate of substitution is decreasing in pollution (i.e., increasing in the environment). That is, if the level of the environment is large at the optimum, the individual is willing to substitute less private consumption for the environment. Finally, we need to find du_2 in order to find the change in the marginal rate of substitution between private consumption of commodity 2 and the environment. We have (details in Appendix A)

$$du_2 = -\tilde{D}\left[p\,dw_0^i + k\,dp + dS\right] - u_2 N_1\, dp/p \tag{31}$$

where $$\tilde{D} \equiv (u_{11}u_{22} - u_{12}u_{21})/D > 0. \tag{32}$$

$\tilde{D}$ is positive since u is strictly concave. From (31) we see that, at the optimum, the marginal utility of commodity 2 is declining in the commodity-1 endowment (a richer individual has a lower marginal utility of commodity 2 at the optimum). The rest of the terms reflect the income effect of the tax-transfer system. An increase in the return on factor k, and in the transfer, reduces the marginal utility of commodity 2.

Equation (13) gives dx as a function of dk and $d\tau^x$; equation (21) gives dp as a function of dk, $d\tau^x$, and dw_0^i. Since dk can be written as a function of dp and dx, we have a system of three equations that gives us dk, dx, dp as functions of $d\tau^x$ and dw_0^i. Substituting for those in (29) and (31) gives $d(\ln[V_1 u_2/(-V_2)])$ as a function of $d\tau^x$ and dw_0^i (see equation (60) in Appendix A). If the environment is non-inferior (i.e., $V_{11}/V_1 - V_{21}/V_2 \leq 0$), commodity 1 and 2 non-inferior ($N_1 \geq 0$, $N_2 \geq 0$), $F_{xk} \geq 0$, $\sigma \geq 0$, and $\eta \geq 0$, then the marginal rate of substitution between the environment and commodity-2 consumption is unambiguously decreasing in w_0^i. This implies that, at the optimum, a poorer individual will have a lower value of the environment as compared to private commodity-2 consumption. If we analyse cases (I) and (II) (production (4*a*)), then $F_{xk} > 0$, $\sigma = 0$, and $\eta = x/k > 0$, it is sufficient that the environment is non-inferior, and the two private goods are non-inferior. Thus, the key is the non-inferiority of goods.

Next, if a higher pollution tax at the optimum reduces pollution, and if the marginal rate of substitution is non-decreasing in the pollution tax, a richer individual prefers a higher pollution tax. By inspection of the second term in (60), we see that if commodity 1 is non-inferior and $\sigma \geq 0$ and $\eta \geq 0$, then the marginal-rate of substitution is increasing in the pollution tax. Again the non-inferiority of commodities plays a role. A richer individual typically wishes a higher environmental tax if she is decisive. The following propositions state sufficient conditions.

Proposition 1 *Assume* A1-A5 *and* $F=F(k,x)$ (*i.e., case* (I) *or* (II)), *then sufficient for an individual marginally poorer (richer) than average (in a situation in which all individuals are the same) to prefer a lower (higher) pollution tax is that*

(i) *the environment is non-inferior* (*i.e.,* $V_{11}/V_1-V_{21}/V_2 \leq 0$),

(ii) *private commodities* 1 *and* 2 *are non-inferior* (*i.e.,* $N_1 \geq 0$ *and* $N_2 \geq 0$).

Proof: See Appendix A.

Proposition 2 *Assume* A1-A5 *and* $F=F(k,x,l)$ (*i.e. case* (III)), *then sufficient for an individual marginally poorer (richer) than average (in a situation where all individuals are the same) to prefer a lower (higher) pollution tax is that*

(i) *the environment is non-inferior* (*i.e.,* $V_{11}/V_1-V_{21}/V_2 \leq 0$),

(ii) *private commodities* 1 *and* 2 *are non-inferior* (*i.e.,* $N_1 \geq 0$ *and* $N_2 \geq 0$).

(iii) $u_{12} \leq 0$, (iv) $F_{xk} \geq 0$, (v) $F_{lxk}l - F_{lxl}l\, F_{xk}/F_{xx} \geq 0$

(vi) $1 - F_{xll}l/F_{xx} \geq 0$, (vii) $F_{xk} - F_{lxk}l \geq 0$, (viii) $-F_{kk}+F_{lkl}l \geq 0$

Proof: See Appendix A.

There are a number of technology assumptions which are sufficient (though not necessary) for a richer individual wanting a higher pollution tax in case (III), (but not in cases (I) and (II)). The reason is that an individual here wishes to redistribute from factor *l*, that is, the labour supply by the future young generation, and the available instruments would be set so as to achieve that.

We have now identified the forces at work in a link between inequality and environmental protection. First, it is the period-1 endowment of the decisive individual in relation to the average. Thus, it is inequality in terms of skewness. Second, the non-inferiority of both environmental and private commodities plays a role.

We can only determine the results with general preferences and technologies for marginal changes in skewness from a position of full equality. Extending it globally generally makes the problem intractable. The reasons are as follows. When analysing the problem for general inequality, two things may happen. First, with or without government taxes, the competitive equilibrium may be a function of the distribution. This happens if Engel curves are non-linear. If one changes the median-mean distance of the distribution, not only the decisive individual's identity changes, but also the competitive equilibrium prices. It is then difficult to assess the political channel. It is therefore desirable to analyse a situation where the competitive equilibrium is invariant with respect to the underlying distribution and only the political channel is at work. This happens when the individual utility function is such that aggregation occurs. There is a broad class of preferences which allows for that. A special case occurs when utility is additively separable and homothetic (logarithmic). This is the reason why in the next section we restrict ourselves to those preferences.

The second consequence may be that decisions are not monotone in the individual's type. Then we may fail to have a median-voter equilibrium. We would then have to look for political institutions that can overcome that problem. That is, however, beyond the scope of this paper.

5. PREFERENCES OVER POLICY (SPECIFIC FUNCTIONS)

For the reasons just mentioned, we will assume that the utility function, u, of private consumption is log-additive and that the production technology is Cobb-Douglas. We retain, however, our general specification over combining utility from private consumption and from pollution (the V function). Thus, we make the following modifications.

A1′ Individuals' preferences

$$V^i = V\left(\ln(c_1^i) + \beta \ln(c_2^i), x\right) \tag{33}$$

where V is strictly concave and $0<\beta\leq 1$.

A3′ Production

$$F(k, l, x) = A l^{1-\alpha-\mu} k^{\alpha} x^{\mu} \tag{34}$$

where $0<\alpha<1$, $0<\mu<1$. A may be dependent on k in the previous period.

Assumption A3′ allows for the production specification (4*a*) when $\alpha+\mu=1$ and allows for endogenous growth in the OLG economy, when $A=\bar{A}k_{-1}^{1-\alpha-\mu}$. Note that additive separability in private consumption goods implies $u_{12}=0$, thus condition (iii) in Proposition 2 is fulfilled. In addition, $u_{12}=0$ implies normality of good 1 and 2 (i.e., $N_1>0$ and $N_2>0$). The log specification implies homotheticity, in turn implying that Engel curves are linear, and inequality will not affect the general-equilibrium prices (inequality will then only work through the political channel, in determining who the decisive individual is). The production technology implies that all conditions (iv)-(viii) in Proposition 2 are fulfilled. Thus, we know that locally (in a neighbourhood of no inequality) there is a positive relationship between the initial endowment of the decisive individual and the resulting pollution tax. We can now extend the results globally. The economic equilibrium is

$$k^i = \frac{\beta}{1+\beta} w\gamma^i - \frac{1}{1+\beta}\frac{S}{p} \qquad (35) \qquad\qquad k = \frac{\beta}{1+\beta} w - \frac{1}{1+\beta}\frac{S}{p} \qquad (36)$$

for individual i and the average/aggregate, respectively.

Using the production technology, we may write the transfer (equation (14)) as

$$S = \left[\alpha + \mu - \alpha(1-\tau^k)\right] F(k, l, x) \qquad (37)$$

Substituting for the transfer (37) into (36) gives k as a function of τ^k and w

$$k = \alpha\beta(1-\tau^k) w_0 \big/ [\alpha + \mu + \alpha\beta(1-\tau^k)] \qquad (38)$$

Taking the derivatives of (36) with respect to p and S and substituting into (19), and using (35), (37) and (38), in (19), gives the capital tax as a function of the endowment of the decisionmaker

$$(1-\gamma^i)\left[\alpha + \mu + \beta(1-\tau^k)\right][\alpha + \mu + \alpha\beta(1-\tau^k)] = (1+\beta)(\alpha+\mu)[\alpha + \mu - (1-\tau^k)] \qquad (39)$$

which gives, as expected, $\partial\tau^k/\partial\gamma^i < 0$. To find the relationship between the decisionmaker's γ and the pollution tax, we need to evaluate (24) (taking into account (39)). The right-hand side of (24) is (by using (34) and (36)),

$$\left[1 - (F_k - F_{lk} l - p)\frac{\partial k}{\partial S}\right] \Big/ \left[\tau^x - F_{lx} l\right] = \frac{\alpha + \mu + \beta(1-\tau^k)}{(1+\beta)(1-\tau^k)(\alpha+\mu)\tau^x} \qquad (40)$$

Next,

$$\frac{1}{u_2} = \frac{pk^i + S}{\beta} = pw\left(\frac{\gamma^i - 1}{1+\beta} + \frac{\alpha+\mu}{\alpha + \mu + \alpha\beta(1-\tau^k)}\right) = pw_0 H \qquad (41)$$

where

$$H \;\equiv\; (\alpha+\mu)(1+\beta)(1-\tau^k)[\alpha+\mu+\beta(1-\tau^k)]^{-1}[\alpha+\mu+\alpha\beta(1-\tau^k)]^{-1} \;>\; 0 \tag{42}$$

The second equality in (41) follows by using (35), (36), (37), and (34) and (38). The last equality in (41) follows from (39). Substituting (40) and (41) into (24) gives $V_1/(-V_2)=F/(\beta\tau^x)$, which differentiated becomes (by using (25))

$$p\,dw^i + k^i dp + dS \;=\; -u_2^{-1}\Omega\left(dF/F - d\tau^x/\tau^x\right) \tag{43}$$

where

$$\Omega \;\equiv\; \frac{1+xV_{22}/V_2 - xV_{12}/V_1}{V_{21}/V_2 - V_{11}/V_1} \tag{44}$$

Note that $\Omega>0$ at least if private consumption and the environment are not inferior goods. Using (37), we have $S=(\alpha+\mu)F-pk$, which differentiated and substituted into the left-hand side of (43) gives

$$p\,dw^i + k^i dp + dS \;=\; pw\,d\gamma^i + p\gamma^i dw + \beta[1+\beta]^{-1}w(\gamma^i-1)dp + (\alpha+\mu)dF - p\,dk \tag{45}$$

Differentiating $p=\alpha(1-\tau^k)F/k$, differentiating (38), using (34) and (13), and substituting into (45) and combining with (43) gives

$$\frac{1-\mu}{H}d\gamma^i \;+\; (\beta\mu+\Omega)\left[\frac{\alpha(\alpha+\mu)}{\alpha+\mu+\alpha\beta(1-\tau^k)}\frac{d(1-\tau^k)}{(1-\tau^k)} - \frac{d\tau^x}{\tau^x}\right]$$
$$+\;[1-\mu+\alpha\beta+\alpha\Omega]\,dw_0/w_0 \;+\; (\beta+\Omega)\,dA/A \;=\; 0 \tag{46}$$

Thus, it is sufficient for a positive relationship between the individual γ and the desired pollution tax, that private consumption and the environment are non-inferior (then $\Omega>0$). We have differentiated with respect to A and w_0 because we need these derivatives for some cases of the model.

6. POLITICO-ECONOMIC EQUILIBRIUM

As argued in section 4, we will have an equilibrium of the median voter type. Individuals vote on candidates characterised by their γ^*. Substitute for policy as a function of γ^* into the indirect utility function to get an indirect utility function in terms of γ^*, say $\tilde{V}^i(\gamma^*)$. We can establish that this function is single peaked with the maximum at $\tilde{V}^i(\gamma^i)$:

Lemma 1 *Assume* A1′, A2, A3′, A4, A5, *then any individual's preferences over representatives are single peaked.*

Proof: See Appendix A.

We have a political equilibrium, and we can analyse policy as a function of γ^*. We will go through the three cases in turn.

Case I - static model

Proposition 3 *Assume* A1′, A2, A3′, A4, A5, *and* $\alpha+\mu=1$, w_0 *fixed, and that private consumption and the environment are non-inferior; then the poorer the median is in relation to the mean (in terms of time endowment), the lower the pollution tax and the higher is the tax on factor k in politico-economic equilibrium. For a given distribution, the greater the productivity is (greater A), the larger the pollution tax is in politico-economic equilibrium.*

Proof: τ^k is decreasing in γ^*, then the result follows from (46). QED

Case II - dynamic model, non-overlapping generations

We examine the no-growth case first:

Proposition 4 *Assume* A1′, A2, A3′, A4, A5, *and* $\alpha+\mu=1$, w_0 *fixed, and that private consumption and the environment are non-inferior; then the poorer the median is in relation to the mean in terms of first-period labour income, the lower the pollution tax is, the higher the capital tax, and the lower the aggregate supply of capital in politico-economic equilibrium. More productive economies (higher A) have a higher pollution tax in politico-economic equilibrium. The economy is always at the steady state.*

Proof: Same as Proposition 3.

We turn to the endogenous-growth case:

Proposition 5 *Assume* A1′, A2, A3′, A4, A5, *and* $\alpha+\mu=1$, $w_0=\omega k_{-1}$, *and that private consumption and the environment are non-inferior, then the poorer the median is in relation to the mean in terms of first-period labour income, the higher the capital tax, and the lower the growth rate in politico-economic equilibrium. For any given capital stock, the poorer the median is in relation to the mean, the lower the pollution tax is. The economy is always on the steady state growth path.*

Proof: Substitute for w_0 by using $w_0=\omega k_{-1}$ in (38). This gives

$$k/k_{-1} = \alpha\beta(1-\tau^k)\,\omega \,/[\alpha + \mu + \alpha\beta(1-\tau^k)] \tag{47}$$

Since τ^k is decreasing in γ^*, then the result follows from (47) and (46). QED

Case III - dynamic model; overlapping generations

In the no endogenous-growth case (i.e., *A* is constant), we have

Proposition 6 *Assume* A1′, A2, A3′, A4, A5, *and* $\alpha+\mu<1$, *then it is sufficient for global* *stability of the economy under the endogenous tax programme that*

$$\frac{1 + xV_{22}/V_2 - xV_{12}/V_1}{V_{21}/V_2 - V_{11}/V_1} \;>\; \mu\,(1-\beta)/(1+\alpha) \tag{48}$$

The poorer the median is in relation to the mean, the lower the pollution tax is, the greater the capital tax, and the smaller the steady-state capital stock.

Proof: Since $dw_0/w_0 = dF_{-1}/F_{-1}$, using (13), and differentiating F (equation (34)) gives

$$\frac{w_0}{F}\frac{dF}{w_0} \;=\; \frac{\alpha}{1-\mu}\frac{w_0}{k}\frac{dk}{dw_0} - \frac{\mu}{1-\mu}\frac{w_0}{\tau^x}\frac{d\tau^x}{dw_0} \;=\; \frac{\alpha\Omega - \mu}{\beta\mu + \Omega} \tag{49}$$

The second equality follows by (38) and by (46). For stability, the right-hand side needs to be less than unity in absolute value. Then (48) follows. QED

Thus, the economy is always stable if $\beta \geq 1$ and private consumption and the environment are non-inferior.

Proposition 7 *Assume* A1′, A2, A3′, A4, A5, $\alpha+\mu<1$, *and* $A=\bar{A}k_{-1}^{1-\alpha-\mu}$ *and that private consumption and the environment are non-inferior. Then there is a a balanced endogenous growth path. The poorer the median individual is in relation to the mean the lower the growth rate is. For any given capital stock, the pollution tax is smaller.*

Proof: Follows by differentiating F, then F and k grow at the same rates. By inspection of (38), the larger the capital tax is (for given level of past k), the smaller the next period's k is. Since τ^k is decreasing in γ^*, the inequality-growth result follows. The inequality pollution result follows from (46). QED

Thus, the various cases produce the same predictions regarding inequality and environmental protection, and the models allowing for growth, produce lower growth for higher inequality. Therefore our prediction is also that growth and environmental protection are positively related in political-economic equilibrium. We will now turn to the empirical evidence.

7. THE EVIDENCE

7.1 Data

For our empirical analysis, we use two samples. The first includes seven industrialised countries: Australia, Canada, Germany, Norway, Sweden, the UK and the US, over the period 1978-1997, in turn divided into four subperiods of five years each: 1978-1982, 1983-1987, 1988-1992, 1993-1997, so that we have four observations for each country (summary statistics for each variable are given in Table 1; the data are reported in Annex 1). The second sample is obtained by adding three additional countries, i.e. Finland, Italy and Luxembourg, to the seven above (for a total of 10 countries). The time subperiods are: 1983-1987, 1988-1992, 1993-1997, that is, we drop the first subperiod of the previous sample because of lack of data (summary statistics are displayed in Table 5; the data are reported in Annex 2).

[Table 1 approximately here]

The choice of these panels is mainly determined by the availability of income distribution data. International comparability of income distribution data is a difficult matter. For example, data are made available through national surveys which take place at different dates for each country. Also, the definition of income used in the survey may vary across countries, for example, whether it is before or after taxes and transfers. Furthermore, the units of observation may either be the households (when the unit of observation is identified by the common residence) or the family (that is a group linked by a blood or legal relationship). To overcome these problems, we use the Luxembourg Income Study (LIS) database. LIS has developed internationally comparable income distribution data for a number of countries. The time period for which data are available differs across countries, but it generally covers the eighties and mid-nineties. The LIS definition of income is households' disposable income that includes transfers and that is after income taxes and social security contributions. In order to account for the skewness of the income distribution that, in our model plays the key role (i.e., the distance between mean and the average income), we use LIS data on percentile ratios and, in particular, the ratio of households ranked at the top 90th percentile (P90) to the median household (P50). The higher the ratio, the higher the inequality. This ratio, which in our regressions is called INE, ranges from 1.51 (for Sweden in 1987 and 1992) to 2.19 (for the US in 1994).

Environmental protection is proxied by air pollution per unit of GDP, under the assumption that a stringent environmental policy decreases equilibrium polluting emissions.[9,10] Air pollution data which are easily available include Sulphur (SO_2), Nitrogen Oxides (NO_2) and Carbon Dioxide (CO_2) emissions. However, reducing Sulphur and Nitrogen

[9] We think that, from an empirical point of view, the level of polluting emissions captures the stringency of environmental policy better than, for example, energy taxes. In theory, energy taxes reflect concern about the environment since high energy prices discourage the use of polluting energy products. However, in practice, it is difficult to assess whether taxes have effectively decreased pollution. That may not be the case if the government also subsidises energy products at the same time.

[10] To our knowledge, the development of a single indicator of environmental stringency which a) accounts for the effectivness of environmental policy on a number of environmental problems such as air and water pollution, waste, deforestation; b) is calculated across countries; and c) overtime, has not been attempted yet. Van beers and van der Bergh (1997) have constructed an indicator of environmental-policy stringency for a number of OECD countries, but only for 1990. In our regressions, we could separately introduce other proxies for environmental protections such as waste recycling, number and extension of protected areas, water pollution etc.; however, we leave this for future work.

Oxides emissions has been the target of International Environmental Agreements since the mid-eighties,[11] while international commitments to reduce Carbon emissions were made only in the earlier nineties, since the UN Convention on climate change, adopted in Rio de Janeiro in 1992.[12] To abstract from the effects of the commitment of developed countries to the international environmental agreements of the mid-eighties, we chose to use CO_2 emissions as a proxy for air pollution. In our regressions, te ratio of CO_2 emissions and total GDP is called EMIS. Therefore, a low EMIS value suggests that environmental policy is stringent. In our sample, the minimum value for this variable is 63.6 Kg of Carbon per 1,000 US dollars (for Norway in 1993-1997) and the maximum is 328.3 Kg of Carbon per 1,000 US dollars (for the US in 1978-1982).

Growth is expressed as the annual average of growth rate of GDP per capita (continuously compounded from OECD National Accounts data). This variable is called GRO in our regressions and ranges from -0.86% (for Canada in 1988-1992) to 3.18% (for Norway in 1993-1997).

In all our regressions, we include GDP per capita, which we call GDP, to take into account the effect of higher average national income on environmental policy, and the eventual slowdown of growth at high GDP levels. GDP ranges from 13,224 thousands of US dollars (for the UK in 1978) to 32,222 thousands of US dollars (for Sweden in 1993). All variables have been calculated as annual averages, except GDP, which has been recorded at the beginning of each five-year period (and as such is considered a predetermined variable),

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[11] Namely, the 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes and the 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides or their Transboundary Fluxes.

[12] In December 1997 at Kyoto, the parties to the Climate Change Convention agreed on a legally binding commitment of developed countries to reduce emissions of greenhouse gasses by the period 2008-2012.

and the income inequality measure (INE), for which only one observation per country was generally available in each time subperiod.[13] The data are shown in Annex 1. Appendix B describes the data sources and definitions. Table 1 below displays summary statistics for the variables used in our regressions and the correlation coefficients. To test the sensitivity of the regressions to changes in the sample, we use a 10-country panel, across three periods of time: 1983-1987, 1988-1992, 1993-1997 (that is we drop the first time period of the 7- country sample, since the countries which we newly introduce into this sample, i.e., Finland, Italy and Luxembourg lack data on inequality for the first period), for a total of 30 observations. The data for the 10-country sample are reported in Annex 2; descriptive statistics are displayed in Table 5.

7.2 Results

The purpose of our empirical analysis is to provide evidence for the theoretical relationships found in section 6, namely, that pollution and inequality are positively related and that growth and pollution are negatively related. It is not our aim to offer an exhaustive explanation of growth rates, inequality, or pollution. Indeed, many determinants of growth and inequality which have been found significant in other studies, such as education and fertility,[14] or variables which can influence pollution emissions such as industry structure, are not included in our model.

The results of our regression are displayed in Tables 2, 3, and 4 for the 7-country sample

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[13] Most of the available observations refer to the middle of the time period. Ideally, we would have liked to measure income inequality at the beginning of the time period (predetermined variable) to exclude a reverse causality problem in the regressions where the inequality variable is present. One should, however, notice that most of the variation in this variable is cross-country and not over time. Furthermore, running all regressions with inequality lagged one period did in fact not change our results

[14] See, for example, Persson and Tabellini (1994) and Galor and Zang (1997).

and in Tables 6, 7, and 8 for the 10-country sample. For all our regressions, we report results from simple OLS (denoted as OLS in the tables), from Maximum Likelihood iterative technique to correct for autocorrelation (ML) and from fixed effect, panel data techniques (FE). Since tests for autocorrelation do not have enough power in the short-time dimension we have in our samples, we need to check the sensitiveness of the OLS estimates to autocorrelation. Furthermore, in order to assess whether OLS estimates may be sensitive to country-specific characteristics omitted from the regression, we perform fixed effect estimation. First, we study the relationship between inequality and air pollution where pollution is the dependent variable. We would expect higher inequality to cause higher pollution, and higher GDP to result in less pollution (environment being a normal good). Subsequently, we explore the relationship between growth and pollution and growth and inequality with growth as the dependent variable in both regressions; we expect a positive relationship between pollution and growth, and for the inequality-growth regression, we expect to verify a negative relationship. In all the regressions, we include GDP per capita, which is expected to have a negative sign (higher level of GDP causing slowdown in growth). The reason for not including INE and EMIS in the same regression for GRO is that we want to establish the influence on the dependent variable of each independent variable separately.[15]

We start analysing the 7-country sample. Table 2 reports the results for the pollution regression; the coefficients for inequality and GDP per capita are significant and display the expected signs both in the OLS and the ML regression, where the constant has been omitted since it was insignificant. In the FE regression, the coefficient of INE shows the wrong sign and is significant, leading us to argue that we cannot rule out an omitted variable problem in the OLS and ML regressions.

[15] Including INE and EMIS in the same growth regression would give rise to a multicollinearity problem.

[Table 2 approximately here]

Table 3 shows the results from the growth regression on pollution. The signs are always as expected and the coefficients are always significant and robust to autocorrelation and to variables omission.

[Table 3 approximately here]

The relationship between GRO and INE turns out to be the most difficult to explain (see Table 4).[16] In both OLS and ML regressions, the coefficient of INE presents the expected sign, but it is significant only in the ML regression. In the FE regression, the INE coefficient displays the wrong sign, but it is insignificant; furthermore, the R^2 turns out to be negative, meaning that the country-specific effects do not add explanatory power. We have also experimented with a shorter time dimension (the last three subperiods) and with INE lagged one (to rule out simultaneity between INE and GRO and INE and EMIS) and we always obtained the above relationships.[17]

[Table 4 approximately here]

Next, we estimate the same regressions for the 10 countries sample (30 observations) to check whether changes in the time and cross-country dimensions may lead to different relationships (see Tables 6, 7, 8). For all regressions, excepted the regression of GRO on EMIS, we obtain the same results as in the seven countries sample.[18] In the regression of

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[16] This relationship is not the focus of our paper. More extensive empirical studies have already found evidence of a negative correlation between inequality and growth (see, among others, Persson and Tabellini, 1994 and Benabou, 1996).

[17] Furthermore, to rule out any reverse causation problem we tried to regress our dependent variables lagged one on the same independent variables. We have never found significant relationships.

[18] We also performed regression analysis for a sample of 14 counties along two periods of time: 1988-1992 and 1993-1997; furthermore, we repeated all the estimations for all samples over different time periods (still five-years each) beginning in the mid-seventies. The coefficient always presented the expected sign, although their significance was decreasing with the reduction of the time dimension. The complete estimation procedure is available from the authors on request.

GRO on EMIS the coefficient of EMIS takes on the wrong sign in the OLS and ML regression, but is insignificant. In the FE regression, the same coefficient turns out to be negative (as expected) and significant. One would expect that adding countries to the sample increases the cross-country heterogeneity and this would result in an omitted variable problem and biased coefficients in the OLS and ML regressions. Indeed, countries may differ in terms of industry structure and technology, and this has consequences for the desired use of pollution.

8. CONCLUSIONS

The paper has explored whether income distribution within a country is a determinant in shaping political decisions regarding the protection of the environment. We have presented an overlapping-generations model where individuals differ in period-1 labour income. This model could also be interpreted as (I) a static model, where individuals differ in productive time, supply labour, and labour is taxed, or (II) a non-overlapping-generations dynamic model, where individuals differ in period-1 labour. The period-1 wage could either be constant or a function of past generation's savings (in that case, generating endogenous growth). In the various modifications, we found a relationship between inequality in terms of median-mean distance and pollution. The driving forces are two-fold. A poorer individual has a lower marginal rate of substitution between the environment and private consumption (if environment is a non-inferior good). This causes a poorer individual to protect the environment less (if she was to decide policy). The second force is that a poorer individual wishes to redistribute, thereby distorting the production decision and causing less production. If the environment is a non-inferior good, this causes any individual to prefer more private consumption in relation to the environment. These forces work in the same direction.

We also explored the issue of growth. A poorer individual wishes to redistribute more and levy higher capital taxes. This, in our model, hampers capital accumulation and growth. Since we found a negative relation between inequality and growth, and a negative relation between environmental protection, we have verified a positive relationship between growth and environmental protection.

Finally, we tested the theoretical predictions and found supporting evidence from a panel of seven industrialised countries. However, when we extended the sample to 10 developed countries, we noticed that country-specific characteristics which are not captured by our model, for example, different industry structures and technology, may play a relevant role in explaining the relationship between growth and environmental protection.

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APPENDIX A

Derivation of (31)

Differentiating du_2 gives

$$du_2 = u_{21}\left(dw_0^i - dk^i\right) + u_{22}\left(pdk^i + k^i dp + dS\right) \tag{50}$$

or

$$du_2 = u_{21} dw_0^i + p\left(u_{22} - u_{21}\right)\left[\frac{\partial k^i}{\partial p} dp + \frac{\partial k^i}{\partial S} dS + \frac{\partial k^i}{\partial w_0^i} dw_0^i\right] + u_{22}\left(k^i dp + dS\right) \tag{51}$$

or by using (7)-(9), and N_1+N_2=1,

$$du_2 = \left[u_{22} N_2 + u_{21} N_1 / p\right]\left(p dw_0^i + kdp + dS\right) + D^{-1}\left(p u_{22} - u_{21}\right) u_2 dp \tag{52}$$

Using (10)-(11) gives (31).

Proof of Propositions 1-2

Using the last equality in (27) to substitute for *kdp*+*ds*, and combining with (29) gives

$$d\ln\left(\frac{V_1 u_2}{-V_2}\right) = \left[\left(\frac{V_{11}}{V_1} - \frac{V_{21}}{V_2}\right) u_1 - p\frac{\tilde{D}}{u_2}\right] dw_0^i - \left[\frac{V_2}{V_1} Q - \frac{\tilde{D}}{u_2} F_{xx}\,\pi\right] dx - \frac{N_1}{p} dp \tag{53}$$

where

$$\pi \equiv \left(F_x - F_{lx} l\right) / \left(-F_{xx}\right) \tag{54}$$

Next, differentiating k

$$dk = \frac{\partial k}{\partial p} dp + \frac{\partial k}{\partial S} dS = \frac{u_2}{D} dp - \frac{N_1}{p}\left(kdp + dS\right) \tag{55}$$

where the last equality follows from (8)-(9). Then, by using the last equality in (27), and the definition (54), we have

$$dk \;=\; D^{-1}u_2 dp \;+\; p^{-1}N_1 F_{xx}\pi dx \tag{56}$$

Equations (56), (13), (14) form a system, such that *dk*, *dx*, and *dp* can be solved for. The latter two are

$$F_{xx}(1+m)dx \;=\; \left[1 + D^{-1}u_2\left(\rho + \eta F_{xk}\right)\right]d\tau^x - F_{xk}N_2 dw^i \tag{57}$$

and

$$(1+m)dp \;=\; N_2 D u_2^{-1}\left(1 + F_{xk}N_1\pi/p\right)dw^i \;-\; \left[\eta + \frac{N_1}{p}\pi\left(\sigma + \eta F_{xk}\right)\right]d\tau^x \tag{58}$$

where

$$m \equiv \sigma D^{-1}u_2 + F_{xk}N_1\pi/p \tag{59}$$

Substituting (57) and (58) into (53) gives

$$\begin{aligned} d\ln\left(\frac{V_1 u_2}{-V_2}\right) = & \left[\left(\frac{V_{11}}{V_1} - \frac{V_{21}}{V_2}\right)u_1 + \frac{V_2}{V_1}\frac{F_{xk}}{F_{xx}}\frac{QN_2}{1+m} - \frac{\tilde{D}}{u_2}\left(p + \frac{F_{xk}\pi N_2}{1+m}\right) - \frac{N_1 N_2 D}{p(1+m)u_2}\left(1 + F_{xk}\frac{N_1}{p}\pi\right)\right]dw^i \\ & - \left[\left(\frac{V_2}{V_1}Q - \frac{\tilde{D}}{u_2}F_{xx}\pi\right)\frac{1 + \dfrac{u_2}{D}(\sigma + \eta F_{xk})}{F_{xx}(1+m)} - \frac{N_1}{p(1+m)}\left(\eta + \frac{N_1}{p}\pi(\sigma + \eta F_{xk})\right)\right]d\tau^x \end{aligned} \tag{60}$$

Next differentiating the log of the numerator and the denominator of the right-hand side of (24) gives, respectively

$$d\ln\left[1 - \left(F_k - F_k l - p\right)\frac{\partial k}{\partial S}\right] \;=\; -\frac{\partial k}{\partial S}d\left(F_k - F_{lk}l - p\right) \;=\; \frac{\partial k}{\partial S}N_2\frac{D}{u_2}dw^i \;=\; -\frac{N_1 N_2 D}{pu_2}dw^i \tag{61}$$

$$d\ln\left(F_x - F_{lx}l\right) \;=\; \frac{d\tau - F_{lxk}ldk - F_{lxk}ldx}{F_x - F_{lx}l} \tag{62}$$

Next, combining (60), (61), and (62), the differential of the log of the first-order condition (24) is

$$
\begin{aligned}
& d\ln\left(\frac{V_1 u_2}{-V_2}\right) - d\ln[1-(F_k - F_{kl}l - p)\frac{\partial k}{\partial S}] + d\ln(F_x - F_{lx}l) = \\
& = \left[\left(\frac{V_{11}}{V_1} - \frac{V_{21}}{V_2}\right)u_1 + \frac{V_2}{V_1}\frac{F_{xk}}{F_{xx}}\frac{QN_2}{1+m} - \frac{\tilde{D}}{u_2}\frac{p+F_{xk}\pi}{1+m} + \frac{\sigma}{1+m}\frac{u_{12}}{D}\right]dw^i \\
& + \left[\left(\frac{-V_2}{V_1}\frac{Q}{F_{xx}} + \frac{\tilde{D}}{u_2}\pi\right)\frac{1+\frac{u_2}{D}(\sigma+\eta F_{xk})}{1+m} + \frac{N_1}{p}\frac{\eta + \frac{N_1}{p}\pi(\sigma+\eta F_{xk})}{1+m} + \frac{1}{-F_{xx}\pi}\right]d\tau^x \\
& + \frac{F_{lxk}l\,dk + F_{lxl}l\,dx}{F_{xx}\pi}
\end{aligned}
\tag{63}
$$

We have used the relation

$$
\begin{aligned}
& -\frac{\tilde{D}}{u_2}p - \frac{\tilde{D}}{u_2}F_{xk}\pi\frac{N_2}{1+m} - \frac{N_1 N_2 D}{p(1+m)u_2}\left(1+F_{xk}\frac{N_1}{p}\pi\right) + \frac{N_1 N_2 D}{pu_2} = \\
& = -\frac{\tilde{D}p}{u_2(1+m)}\left[1+m+F_{xk}\pi\frac{N_2}{p}\pi\right] + \frac{N_1 N_2 D}{p(1+m)u_2}\left(m - F_{xk}\frac{N_1}{p}\pi\right) \\
& = -\frac{\tilde{D}p}{u_2(1+m)}\left[1+\sigma\frac{u_2}{D}+F_{xk}\frac{\pi}{p}\right] + \sigma\frac{N_1 N_2}{p(1+m)} \\
& = -\frac{\tilde{D}p}{u_2(1+m)}\left[1+F_{xk}\frac{\pi}{p}\right] - \frac{\sigma p}{1+m}\left(\frac{\tilde{D}}{D} - \frac{N_1}{p}\frac{N_2}{p}\right) \\
& = -\frac{\tilde{D}p}{u_2(1+m)}\left[1+F_{xk}\frac{\pi}{p}\right] + \frac{\sigma}{1+m}\frac{u_{12}}{D}
\end{aligned}
\tag{64}
$$

We need to evaluate the last term in (63). Using (57) and (58) in (56) gives

$$
(1+m)dk = N_2 dw^i - \left(\eta D^{-1}u_2 - N_1\pi/p\right)d\tau^x \tag{65}
$$

Since $F_{lxk}\geq 0$, dk enters with negative sign in (63), and since $F_{lxl}\leq 0$, dx enters with positive sign. dk and dx are positively and negatively related, respectively, to dw^i. Therefore, the last term will add dw^i negatively, and the function (63) is unambiguously negative in dw^i. The terms in τ^x are at first sight ambiguous, and we have to add those terms carefully.

$$\frac{F_{lxk}l}{F_{xx}\pi}dk + \frac{F_{lxl}l}{F_{xx}\pi}dx = \frac{1}{-F_{xx}\pi(1+m)}\left[F_{lxk}l\left(\eta\frac{u_2}{D} - \frac{N_1}{p}\pi\right) - \frac{F_{xll}l}{F_{xx}}\left(1+\frac{u_2}{D}(\sigma+\eta F_{xk})\right)\right]d\tau^x - Mdw^i$$

(66)

where

$$M \equiv \frac{N_2}{-F_{xx}\pi(1+m)}\left[F_{lxk}l - F_{xll}l\frac{F_{xk}}{F_{xx}}\right] \tag{67}$$

Substituting into (14) gives

$$\left[\left(\frac{V_{11}}{V_1} - \frac{V_{21}}{V_2}\right)u_1 + \frac{V_2}{V_1}\frac{F_{xk}}{F_{xx}}\frac{QN_2}{1+m} - \frac{\tilde{D}}{u_2}\frac{p+F_{xk}\pi}{1+m} + \frac{\sigma}{1+m}\frac{u_{12}}{D} - M\right]dw^i$$
$$+\left[\left(\frac{-V_2}{V_1}\frac{Q}{F_{xx}} + \frac{\tilde{D}}{u_2}\pi\right)\frac{1+\frac{u_2}{D}(\sigma+\eta F_{xk})}{1+m} + \frac{N_1}{p}\frac{\eta+\frac{N_1}{p}\pi(\sigma+\eta F_{xk})}{1+m} + \tilde{M}\right]d\tau^x = 0 \tag{68}$$

where

$$\tilde{M} \equiv \frac{1}{-F_{xx}\pi(1+m)}\left[\left(1+\sigma\frac{u_2}{D}\right)\left(1-\frac{F_{xll}l}{F_{xx}}\right) + \frac{N_1}{p}\pi(F_{xk}-F_{lxk}l) + \eta\frac{u_2}{D}\left(F_{lxk}l - F_{xll}l\frac{F_{xk}}{F_{xx}}\right)\right] \tag{69}$$

Then Propositions 1 and 2 follow from (67), (68), and (69). QED

Proof of Lemma 1

Use (37) to substitute for S, and the relation $p=\alpha\theta F/k$, in (33)

$$V^i = V\big(u(w\gamma^i - k^i, [\alpha\theta(k^i/k - 1) + \alpha + \mu]F), x\big) \tag{70}$$

Since x is a function of k and τ^x (equation (13)), we may write $x=\tilde{x}(k,\tau^x)$ and $F(k,x,l)=\tilde{F}(k,\tau^x)$. Then treating θ and τ^x as functions of the gamma of the decisionmaker, γ^*, and differentiating with respect to γ^*, we have

$$\frac{\partial V^i}{\partial \gamma^i} = V_1 u_2 \left\{ \alpha\left(\frac{k^i}{k} - 1\right) F - \alpha \frac{k^i}{k}\frac{\theta}{k}\frac{\partial k}{\partial \theta} F + \left[\alpha\theta\left(\frac{k^i}{k} - 1\right) + \alpha + \mu\right]\tilde{F}_k \frac{\partial k}{\partial \theta} + \frac{V_2}{V_1 u_2}\tilde{x}_k \frac{\partial k}{\partial \theta}\right\}\frac{\partial \theta}{\partial \gamma^*} \tag{71}$$
$$+ V_1 u_2 \left\{\left[\alpha\theta\left(\frac{k^i}{k} - 1\right) + \alpha + \mu\right]\tilde{F}_{\tau^x} + \frac{V_2}{V_1 u_2}\tilde{x}_{\tau^x}\right\}\frac{\partial \tau^x}{\partial \gamma^*}$$

When $\gamma^j=\gamma^*$, the terms within the curly brackets are zero. We need to prove that the marginal utility of a candidate increases if $\gamma^*<\gamma^j$, and decreases if $\gamma^*>\gamma^j$, i.e., that the terms within the curly brackets are positive (negative) for $\gamma^*<\gamma^j$ ($\gamma^*>\gamma^j$).

Next we need the relation

$$\beta u_2^{-1} = \left[\alpha\theta(k^i/k - 1) + \alpha + \mu\right]F \tag{72}$$

Since $k\tilde{F}_k/F=\alpha/(1-\mu)$, $\tau^x\tilde{F}_{\tau^x}/F=-\mu/(1-\mu)$, $k\tilde{x}_k/x=\alpha/(1-\mu)$, and $\tau^x\tilde{x}_{\tau^x}/x=-1/(1-\mu)$, substituting for those derivatives in (71), using (72) and rearranging gives

$$\frac{\partial V^i}{\partial \gamma^*} = V_1 u_2 \left\{\left[\alpha\theta F\left(\frac{k^i}{k} - 1 - \frac{k^i}{k}\frac{\theta}{k}\frac{\partial k}{\partial \theta}\right) + \frac{\alpha\beta}{u_2}\frac{\theta}{k}\frac{\partial k}{\partial \theta}\right]\frac{1}{\theta}\frac{\partial \theta}{\partial \gamma^*}\right. \tag{73}$$
$$\left. + \frac{1}{1-\mu}\frac{1}{u_2}\left(\frac{-V_2}{V_1}x - \beta\mu\right)\left[\frac{1}{\tau^x}\frac{\partial \tau^x}{\partial \gamma^*} - \alpha\frac{\theta}{k}\frac{\partial k}{\partial \theta}\frac{1}{\theta}\frac{\partial \theta}{\partial \gamma^*}\right]\right\}$$

The term in parentheses is zero at $\gamma^j=\gamma^*$. If the last term within square brackets is non-negative, it is sufficient that the entire expression within the curly brackets is an increasing function of γ^j (for given policy). The k^i's are increasing in γ^j, and $(-V_2/V_1)$ is increasing in γ^j if the environment is non-inferior. Now we only need to prove that the term within the last square bracket is non-negative. Using (46) this turns out to be the case. In fact, it equals $(1-\mu)/H$.

QED

Appendix B: Definitions and Sources of variables

GRO: Average annual growth rate of real GDP per capita continuously compounded and expressed as a percentage, for each country and each 5-year period. Source: Authors calculations using OECD National Accounts for GDP data.

GDP: Real per capita GDP at the beginning of each-5 year period, for each country (thousands US dollars, at 1990 prices and exchange rate). Source: OECD National Accounts.

EMIS: Carbon intensity (kilograms of carbon dioxide ($C0_2$) per US$ 1,000 of total GDP). Annual average for each country and each 5-year period. Carbon emissions are measured at the source and are only from energy use. Source: Authors calculations using OECD Environmental data for CO_2 emissions and OECD National Accounts for GDP.

INE: Income inequality measure; calculated as P90/P50, where P90 and P50 are the 90th percentile and the 50th percentile of the income distribution, respectively. Percentile ratios are the ratios of income levels dividing the specified percentiles of the distribution. Income is defined as household disposable income (including transfers and after income taxes and employee social security contributions). For most countries, only one observation for each 5-year period was available. Source: Luxembourg Income Study database.

Table 1: Summary statistics (7 country, 4 time-periods sample)
Number of Observations: 28

Variable	Mean	Std Dev	Minimum	Maximum
GRO	1.315	1.120	-0.861	3.189
INE	1.802	0.195	=1.510	2.190
EMIS	192.201	78.096	63.602	328.326
GDP	20514.785	5412.958	13245.000	32222.000

Correlation Matrix

Variable	GRO	INE	EMIS	GDP
GRO	1.0000			
INE	-0.052292	1.00000		
EMIS	-0.28041	0.68817	1.00000	
GDP	-0.019070	-0.62770	-0.70736	1.00000

Note: For data sources and definitions see Appendix B

Table 5: Summary statistics (10 country, 3 time-periods sample)
Number of Observations: 30

	Mean	Std Dev	Minimum	Maximum
GRO	0.016742	0.012750	-0.014571	0.035191
INE	1.79367	0.20442	1.51000	2.19000
AIR	0.17553	0.073754	0.063602	0.32392
GDP	21570.13333	5198.76899	13844.00000	32222.00000

Correlation Matrix

	GRO	INE	AIR	GDP
GRO	1.00000			
INE	-0.042773	1.0000		
AIR	0.14067	0.47726	1.00000	
GDP	-0.17222	-0.65730	-0.46516	1.00000

Note: For data sources and definitions see Appendix B

Annex 1: Data for the 7-country sample

Country	Observ.	Time Period	year of the Inc.survey	INE	GDP	GRO	EMIS
Australia	1	1978-82	1981	1.86	14059	0.815937	305.3717
	2	1983-87	1985	1.87	14585	2.552633	259.6222
	3	1988-92	1989	1.95	16958	0.198526	258.3684
	4	1993-97	1994	1.93	17645	2.172710	244.6948
Canada	1	1978-82	1981	1.83	16862	0.183173	299.2840
	2	1983-87	1987	1.84	17385	2.812287	235.0437
	3	1988-92	1991	1.84	20738	-0.861470	229.5378
	4	1993-97	1994	1.85	20077	1.260824	211.5998
Germany	1	1978-82	1978	1.78	16076	0.948494	230.4914
	2	1983-87	1984	1.71	17245	2.020484	201.5963
	3	1988-92	1989	1.7	19654	1.705360	176.2778
	4	1993-97	1994	1.7	20983	1.262117	140.0950
Norway	1	1978-82	1979	1.58	20494	1.786305	98.79253
	2	1983-87	1986	1.62	23111	3.024605	87.02002
	3	1988-92	1991	1.58	26654	1.478832	81.55841
	4	1993-97	1995	1.57	29291	3.189612	63.60219
Sweden	1	1978-82	1981	1.53	27460	1.002284	134.0913
	2	1983-87	1987	1.51	28943	1.328300	111.5718
	3	1988-92	1992	1.51	31630	0.601632	88.08502
	4	1993-97	1995	1.59	32222	0.208304	74.67603
UK	1	1978-82	1979	1.8	13245	0.209014	224.7191
	2	1983-87	1986	1.94	13844	2.793817	188.3597
	3	1988-92	1991	2.06	16637	-0.290192	170.0038
	4	1993-97	1994	2.1	16682	2.255374	149.6439
US	1	1978-82	1979	1.88	18930	-0.537171	328.3269
	2	1983-87	1986	2.06	18882	2.238378	276.6562
	3	1988-92	1991	2.08	21689	0.407019	267.3513
	4	1993-97	1994	2.19	22433	2.066756	245.2101

Note: For data sources and definitions, see Appendix B. The fourth column refers to the date on which the survey on income distribution took place.

Annex 2: Data for the 10-country sample

Country	Observ.	Time Period	year of the inc.survey	INE	GDP	GRO	EMIS
Australia	2	1983-87	1985	1.87	14585	2.552633	259.6222
	3	1988-92	1989	1.95	16958	0.198526	258.3684
	4	1993-97	1994	1.93	17645	2.172710	244.6948
Canada	2	1983-87	1987	1.84	17385	2.812287	235.0437
	3	1988-92	1991	1.84	20738	-0.861470	229.5378
	4	1993-97	1994	1.85	20077	1.260824	211.5998
Finland	2	1983-87	1987	1.51	22066	2.242804	154.8936
	3	1988-92	1991	1.53	25790	-1.457127	126.1456
	4	1993-97	1995	1.59	23571	3.513340	109.0271
Germany	2	1983-87	1984	1.71	17245	2.020484	201.5963
	3	1988-92	1989	1.7	19654	1.705360	176.2778
	4	1993-97	1994	1.7	20983	1.262117	140.0950
Italy	2	1983-87	1986	1.98	15827	2.239032	110.8241
	3	1988-92	1991	1.86	18360	1.283614	107.8452
	4	1993-97	1995	2.02	19278	1.284156	99.85216
Luxemb.	2	1983-87	1985	1.72	18937	3.519122	323.9202
	3	1988-92	1991	1.67	24651	3.438660	272.7272
	4	1993-97	1994	1.73	31336	1.735371	200.1482
Norway	2	1983-87	1986	1.62	23111	3.024605	87.02002
	3	1988-92	1991	1.58	26654	1.478832	81.55841
	4	1993-97	1995	1.57	29291	3.189612	63.60219
Sweden	2	1983-87	1987	1.51	28943	1.328300	111.5718
	3	1988-92	1992	1.51	31630	0.601632	88.08502
	4	1993-97	1995	1.59	32222	0.208304	74.67603
UK	2	1983-87	1986	1.94	13844	2.793817	188.3597
	3	1988-92	1991	2.06	16637	-0.290192	170.0038
	4	1993-97	1994	2.1	16682	2.255374	149.6439
US	2	1983-87	1986	2.06	18882	2.238378	276.6562
	3	1988-92	1991	2.08	21689	0.407019	267.3513
	4	1993-97	1994	2.19	22433	2.066756	245.2101

Note: See note to Annex 1.

Table 2: Regression for EMIS

Independent variable	OLS	ML	FE
Constant	-	-	-
INE	0.176	0.170	-0.131
	(10.853)	(6.491)	(-2.280)
GDP	-0.610E-05	-0.565E-05	-0.868E-05
	(-4.401)	(-2.570)	(-4.681)
No. of observations	28	28	28
adj.R2	0.582	0.718	0.942
SER	0.050	0.042	0.018

Note: OLS denotes standard OLS regression;
ML (maximum likelihood iterative technique) estimates
are corrected for autocorrelation; FE is fixed-effect, panel data
estimates; t-statistics are in parentesis; SER is standard error
of regression.

Table 3: Regression of GRO on AIR

Independent variable	OLS	ML	FE
Constant	0.047	0.037	-
	(2.843)	(3.670)	
EMIS	-0.084	-0.058	-0.309
	(-2.286)	(-2.563)	(-2.865)
GDP	-0.900E-06	-0.639E-06	-0.337E-05
	(-1.691)	(-1.980)	(-2.348)
No. of observations	28	28	28
adj.R2	0.107	0.363	0.212
SER	0.010	0.009	0.009

Note: See note to Table 2.

Table 4: Regression of GRO on INE

Independent variable	OLS	ML	FE
Constant	0.027 (0.806)	0.046 (2.259)	-
INE	-0.006 (-0.414)	-0.013 (-1.606)	0.043 (1.229)
GDP	0.177E-06 (-0.334)	-0.397E-06 (-1.251)	-0.712E-06 (-0.626)
No. of observations	28	28	28
adj.R2	-0.072	0.233	-0.044
SER	0.011	0.009	0.011

Note: See note to Table 2.

Table 6: Regression for EMIS

Independent variable	OLS	ML	FE
Constant	-	-	-
INE	0.133 (6.388)	0.151 (7.246)	-0.087 (-1.557)
GDP	-0.295E-05 (-1.740)	-0.517E-05 (-3.313)	-0.802E-05 (-7.593)
No. of observations	30	30	30
R2	0.265	0.207	0.982
adj.R2	0.239	0.604	0.971
SER	0.064	0.046	0.012

Note: See note to Table 2.

Table 7: Regression of GRO on EMIS

Independent variable	OLS	ML	FE
Constant	0.021	0.013	-
	(1.384)	(1.067)	
EMIS	0.013	0.020	-0.503
	(0.361)	(0.697)	(-2.775)
GDP	-0.334E-06	-0.650E-07	-0.672E-05
	(-0.637)	(-0.150)	(-3.867)
No. of observations	30	30	30
R2	0.034	0.109	0.599
adj.R2	-0.037	0.043	0.355
SER	0.012	0.012	0.010

Note: See note to Table 2.

Table 8: Regression of GRO on INE

Independent variable	OLS	ML	FE
Constant	0.066	0.052	-
	(1.765)	(1.588)	
INE	-0.017	-0.013	0.013
	(-1.116)	(-0.989)	(0.237)
GDP	-0.865E-06	-0.603E-06	-0.256E-05
	(-1.434)	(-1.117)	(-2.478)
No. of observations	30	30	30
R2	0.072	0.113	0.430
adj.R2	0.003	0.058	0.082
SER	0.012	0.012	0.012

Note: See note to Table 2.